Orion GNC / Aero Interfaces

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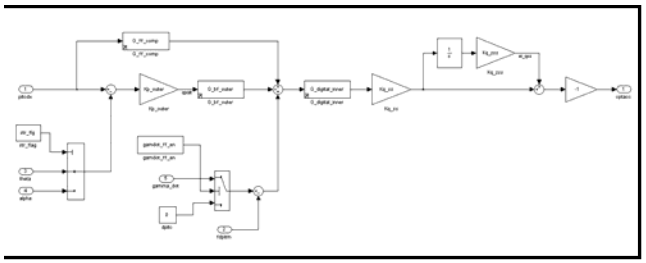
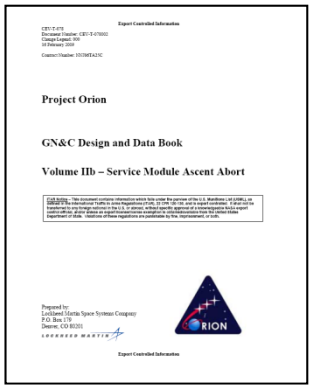
MPCV Flight Dynamics

May 16, 2012

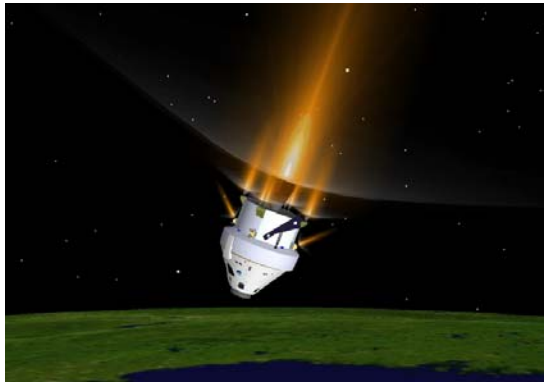
Design



Documentation

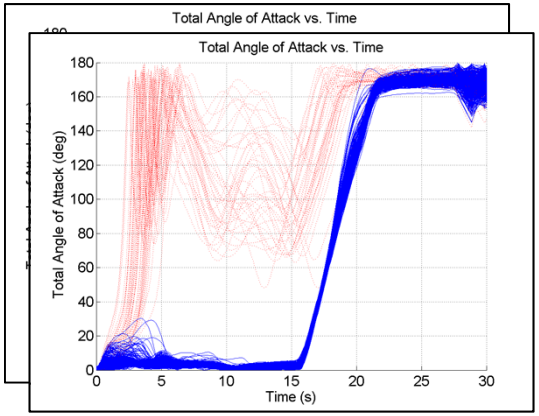


Simulation

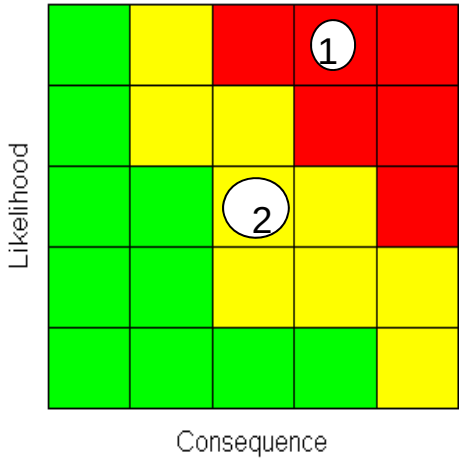


Testing

Ascent Abort Mode Team supports Trajectory Design and Abort Analysis From Design Through Flight Ops



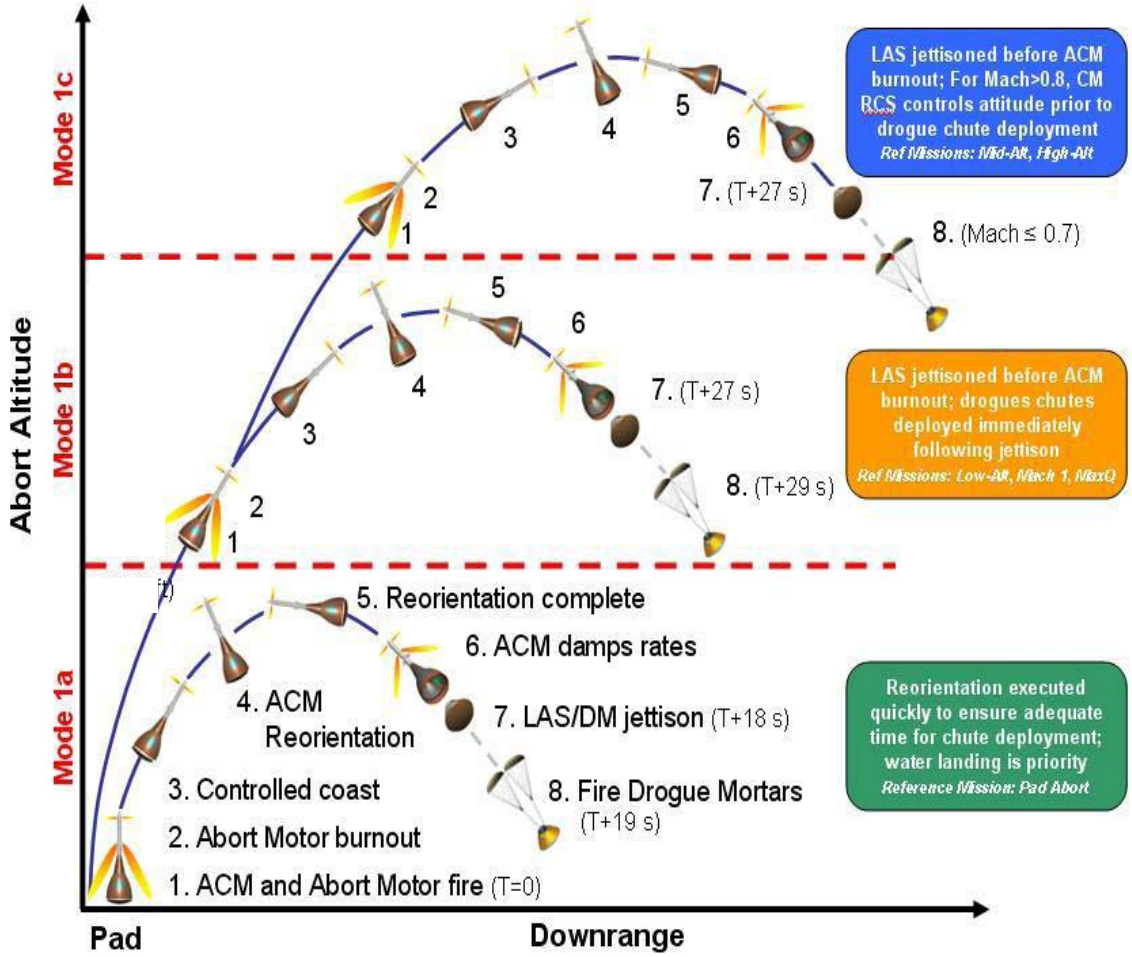
Analysis



Communication

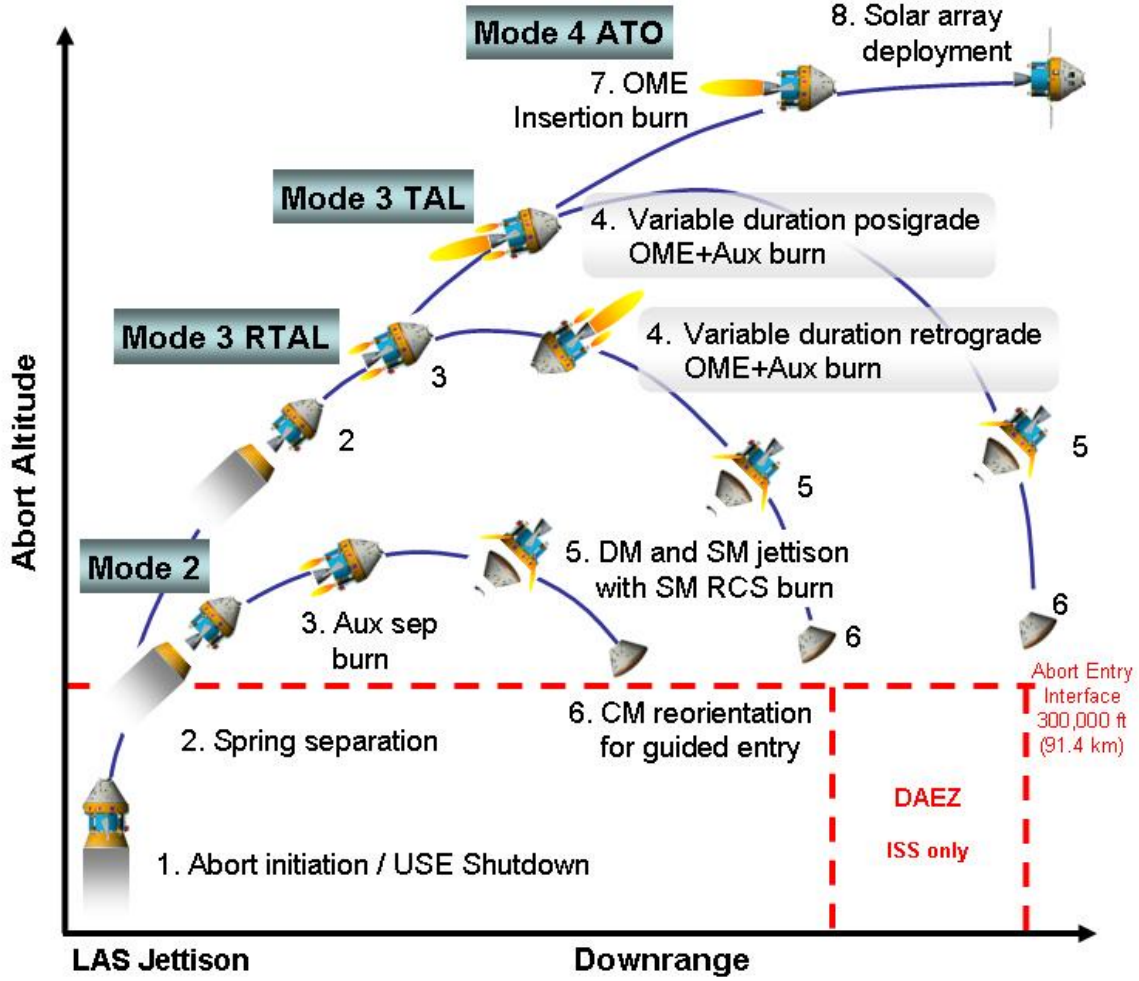
Operations

LAS Abort Con-Ops and Flight Regimes



LAS Aborts rely heavily on aero database due to Abort Motor and Attitude Control Motor Jet Interaction as well as a stressful Mach/Qbar Regime across large ranges of angle of attack

SM Abort Con-Ops and Flight Regimes



SM Aborts rely on CM and CSM aerothermal databases to determine Continuous abort capability across the North Atlantic

Flight Dynamics Performance Process

Orion Project

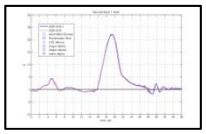
Gather Inputs

- Requirements Documents: Performance Metrics
- Aerodatabase and Uncertainty Formulation
- Simulation Databook: Vehicle Definition
- Launch Vehicle Trajectory Sets: IC's
- Simulation Architecture: 3DOF: POST 6DOF:ANTARES
- Management Decisions Not documented yet
- Prioritized List for Activities, Assessments and Trades

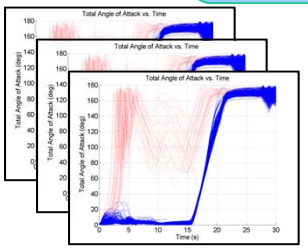
GN&C Algorithm Development

- Start with Output Algorithm from Previous Cycle
- Update Parameters and I-loads for new Orion Vehicle Definition
- Generate Cycle Baseline Results
- Recommend improvements to the Inputs
- Update GN&C Algorithm, Parameters, I-Loads, and ConOps to meet both the GN&C subsystem requirements and the vehicle-wide performance requirements.
- Updated GN&C Design Databook

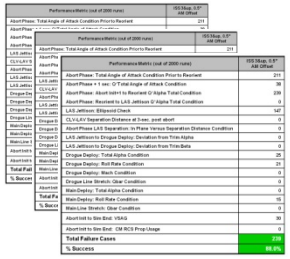
Design Cycle Analysis



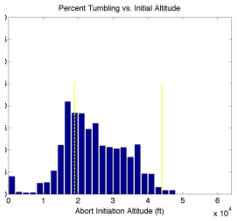
Single Trajectories for some customers who need worst-on-worst, 2-sigma, 3-sigma etc.



Monte Carlo Trajectories for many customers



Individual Monte Carlo Performance



Histograms showing performance for all conditions

Additional Trade Studies

Analysis Documentation

FSW Development

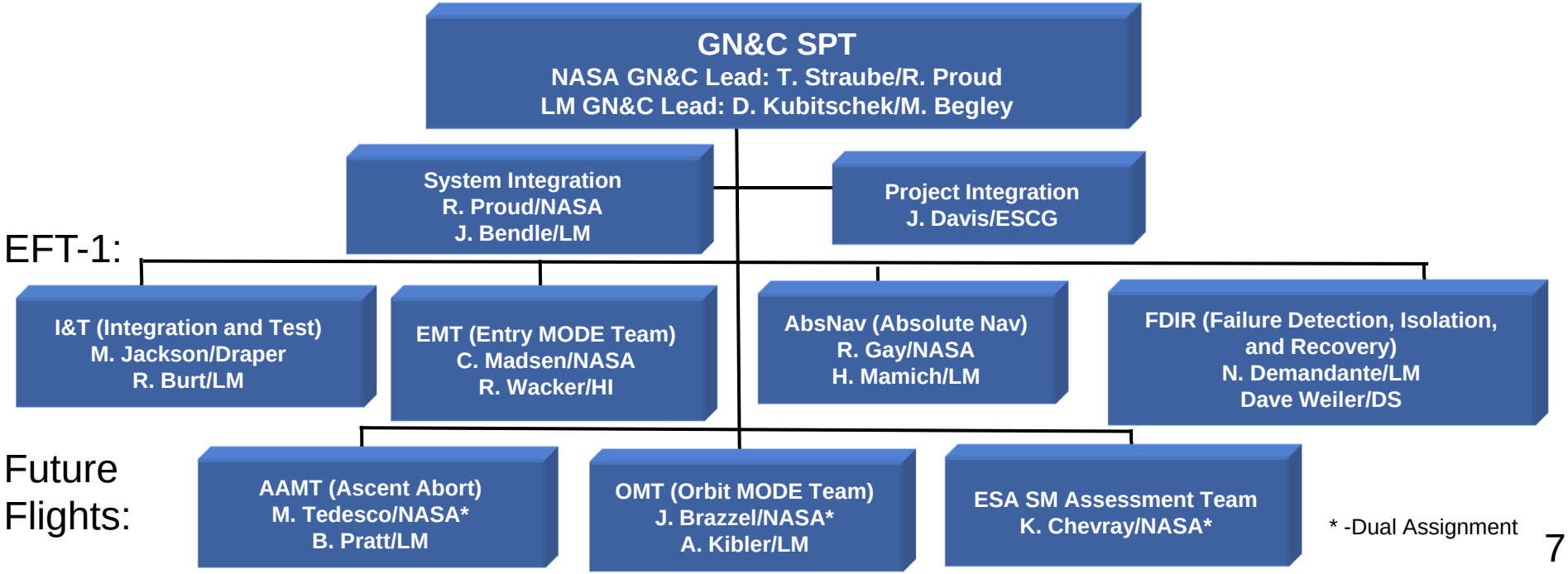
- **Prototype to begin FSW development**
- **Document FSW Change Requests**
- **Implement CR's into the FSW**
- **Test FSW changes**
- **Seek CR approval at FSW Integ. Boards**
- Updated FSW

GNC Requirements Impacted by Aerodynamics/Aerothermal/CPAS

- Maintain continuous abort capability
  - Transonic/Max q region is the bottleneck for capability primarily due to Aerodynamic uncertainties
  - Prior to 26-AA, there was a ~30 second time period during ascent where ~1/3 of Monte Carlo cases lost control authority and tumbled
- Pad abort scenario stresses control authority and chute capability
  - Large pitch over during abort motor burn to achieve water landing exposes vehicle to large Q-alpha-total
  - Low chute deploy stresses ADS to achieve terminal velocity prior to touchdown
- Avoid landing in the Downrange Abort Exclusion Zone (North Atlantic)
  - Constrained by CM aeroheating/loads as well as SM heating due to low T/W
- Subsonic CM dynamic instability resulted in algorithm modifications to avoid flipping apex forward
- ADS twist torque modeling resulted in roll control algorithms under chutes to achieve desired touchdown orientation
  - Which in turn affects CM prop usage and tank sizing
- Entry Aeroheating drives GNC design and accuracy capabilities

Orion GN&C MODE Team

- Orion GN&C is run as a joint development organization with co-leadership and co-authority at the System Product Team (SPT) level and at the MODE team (Flight Phase) level
- All resources and development work below that level are co-managed with resource and skill based tasking
  - Teams hold joint design and development meetings
- All GN&C formal products are flowed up to the SPT level prior to release
  - Majority of decisional topics are discussed at a widely attended SPT meeting including non-GN&C stakeholders
- The prime contractor has final responsibility for production of DRDs although the NASA team owns portions of the content including:
  - GN&C Design Databook, GN&C requirements, GN&C Master Verification Plan, GN&C sensor component specs, etc.



* -Dual Assignment

GN&C Products for Orion

- **GN&C FSW Production**
  - NASA GN&C will design and develop mission algorithms and CSUs jointly with LM GN&C using current production process
- **GN&C Integration, Test and Verification**
  - NASA and LM GN&C will work jointly on the planning, development, execution, analysis, and reporting for all GN&C integration, test and verification work. Including:
    - Verification by analysis
    - Support and execution of ISPs and ITL testing and verification
    - Development and execution of vehicle level O&C level GN&C testing
- **Integrated Vehicle Assessment and Trajectory Release**
  - GN&C jointly will produce integrated 6 DOF trajectories and derived data to support customers (TPS, structures & loads, CPAS, etc) at project integration points.
  - GN&C jointly will perform vehicle level performance and trades during DACs
- **Execution of GN&C System and Subsystem Manager Responsibilities**
  - SM/SSM function is primarily carried out as part of integrated MODE Team. SMs have a dedicated component of their job to accomplish “oversight” (primarily reporting out)
  - NASA GN&C maintains oversight of Orion GN&C HW requirements, reviews, development, and performance
- **Program-To-Program SLS Support**
  - NASA GN&C will provide assessment of SLS trajectory with respect to abort performance and sensitivities at critical program milestones.

Sensor Test for Orion RelNav Risk Mitigation (STORRM) Background

- **STORRM demonstrated the critical technology of automated rendezvous and docking with critical sensor development**
- **The Vision Navigation Sensor provides game-changing innovation in direct range and bearing measurements to a target vehicle or planets**
  - **VNS is real-time flash LIDAR camera capable of simultaneously measuring the 3-dimensional position of several targets with high accuracy**
  - **Eye-safe laser retains output variation and repeatability passively (and also, laser fits into the palm of a hand)**
  - **Lower mass, power and volume than previous generations**
  - **No mechanisms, allowing for high reliability**
- **The Docking Camera demonstrates autonomous and astronaut-guided docking from the vehicle or a ground station**
  - **Small, lightweight and low power**
  - **5-megapixel (COTS) CMOS imaging system for high definition continuous video capture in space applications.**
  - **Automatic gain and exposure control (AGEC) operating within firmware**
    - **Previous units required a processor**
- **Cross-cutting sensor technology applicable for commercial or government applications**

GN&C Hardware-in-the-Loop Testing

- STORRM was flown on Shuttle flight to get real test data for the Orion relative navigation sensors.
- Worked with the Orion Prime contractor to develop a testbed for ground-based testing of the same Orion relative navigation system
  - The Process showed a great comparison between the test flight data and the testbed data.
- GN&C takes the design from initial algorithm concept development, through Flight software development, and into the labs for testing. This process applies to all flight phases.